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Why Feature Dependencies
Challenge the Requirements Engineering
of Automotive Systems:
An Empirical Study

Industry Challenges and Research Needs @ RE 2013

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Driving Dynamics
Dimensioning Functions Driving Dynamics
and Driver Assistance

July 17, 2013

Context: Multifunctional Systems
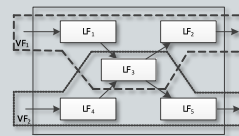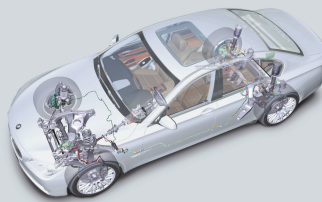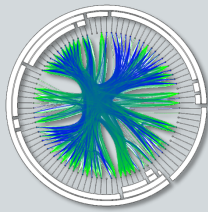
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- Variety of different features
  - serve different purposes
  - behave independently to some extent
- Features can have subtle dependencies and may affect each other in certain situations → *Feature Interaction*
- Requirements management is based on features

ACC
Automatic Hold
Parking Assistant
iBrake
…

Dynamic Cruise Control
Heading Control
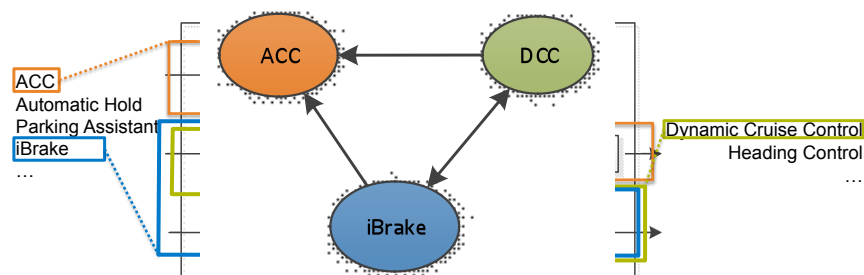…

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Value Proposition:

Feature dependencies in a real automotive system: Numerous, pervasive, implicit, and in many cases unknown to developers.

Vehicle Features and Architecture at BMW

- A vehicle system consists of a set of **vehicle features (VF)**
- A vehicle feature is realized by a set of **leaf functions (LF)**
- Two vehicle features are **dependent** if at least two of their leaf functions **exchange data**

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Research Questions

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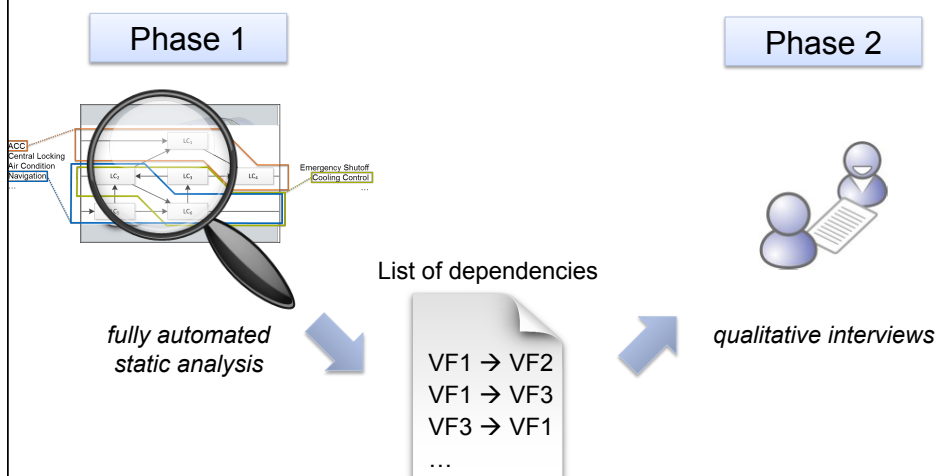**RQ 1:** What is the overall extent and distribution of dependencies between vehicle features?

RQ 2: To what extent are developers aware of feature dependencies?

RQ 3: How important is a comprehensive understanding of functional dependencies and feature interactions?

→ Analysis of the driving dynamics and driver assistance features of a future SUV

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Study Design

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Phase 1

Phase 2

List of dependencies

fully automated static analysis

VF1 → VF2
VF1 → VF3
VF3 → VF1
…

qualitative interviews

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Results for RQ 1: Extent of Dependencies

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Analyzed system:
- Vehicle features: 94
- Feature dependencies: 1451

	Vehicle Features…	Ratio
VF	with incoming dependencies	86.2%
VF	with outgoing dependencies	76.6%
VF	with incoming and outgoing dependencies	72.3%
VF	without dependencies	9.6%

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Results for RQ 1: Distribution of Dependencies

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	Incoming	Outgoing
Maximum	48	53
Median	3	11
Minimum	0	0

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Results for RQ 2: Awareness of Dependencies

- Expert Interviews at BMW
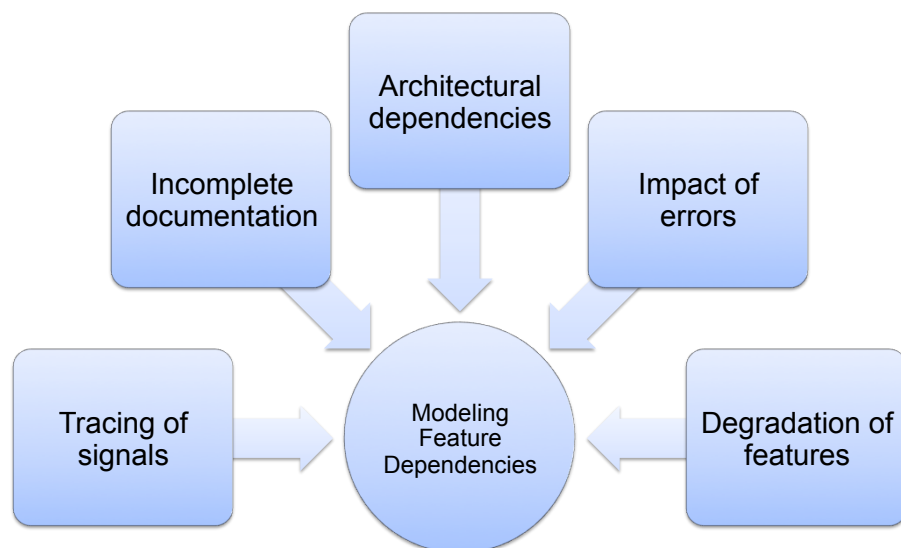- Investigation of 100 feature dependencies (≈ 7%)

	known	unknown	sum
plausible	41 %	48 %	**89 %**
implausible	1 %	10 %	**11 %**
sum	**42 %**	**58 %**	**100%**

Most dependencies are plausible but unknown

The found dependencies are valid

Results for RQ 3: Importance of Awareness

Architectural dependencies

Incomplete documentation

Impact of errors

Tracing of signals

Modeling Feature Dependencies

Degradation of features

Discussion and Implications for Research

Vehicle features as isolated units of functionality?
→ Explicit modeling of dependencies

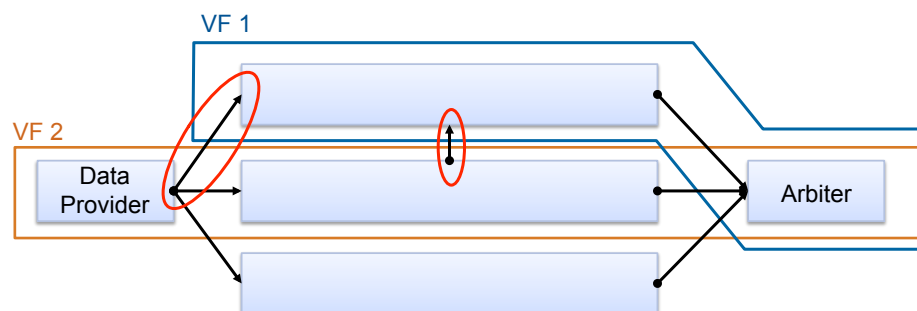Early consideration of feature dependencies in requirements
→ Documentation, specification and analysis

Specifying requirements for vehicle features on the basis of an abstract data model
→ Inputs, outputs and internal conditions

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An interesting observation…

VF 1

VF 2

Data Provider

Arbiter

Feature dependency or architectural dependency?

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Conclusions and Future Work

Conclusions:

1. Dependencies between vehicle features are numerous and pervade the whole system
2. Developers are mostly unaware of these dependencies
3. Feature dependencies should be modeled early on a feature level

Future Work:

– Separate the pure feature dependencies from the architectural dependencies
– Describe feature dependencies on the basis of a mode model
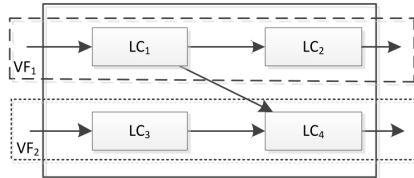
Thanks for the attention.

Special thanks to:
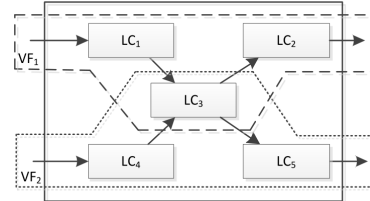The interviewees from BMW, Maximilian Junker, Benedikt Hauptmann

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Backup

2 Types of Dependencies

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Dependent by exchanging data

Dependent by sharing a common component
→ Cannot be ensured definitely

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Threats to Validity

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Threats to the internal validity
– Realization/implementation vs. requirements
– Definition of dependency

Threats to the external Validity
– Analysis only performed on a single system

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